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Investigation of the Mechanical Properties of Epoxy Impregnated NbTi Composite

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The mechanical properties of a epoxy impregnated NbTi composite were investigated at room temperature and at 4.2 K. The modulus of elasticity and the Poisson's ratio were obtained along the axial, azimuthal and radial directions. The ten-stack samples were impregnated with CTD-101K and 828/NMA/DMP-30 epoxy systems using the procedure outlined in the tech-note, TD-98-059.

ROOM TEMPERATURE MEASUREMENTS

The samples were cut for mechanical testing using a low speed diamond saw and Fig. 1 shows one such sample (also shown in the figure are the direction convention used in this study). The samples were then instrumented with strain gauges along the loading direction and transverse to the loading direction to obtain both modulus and Poisson's ratio. The gage resistance were measured using four-wire measurement technique with a high resolution digital multimeter (DMM).

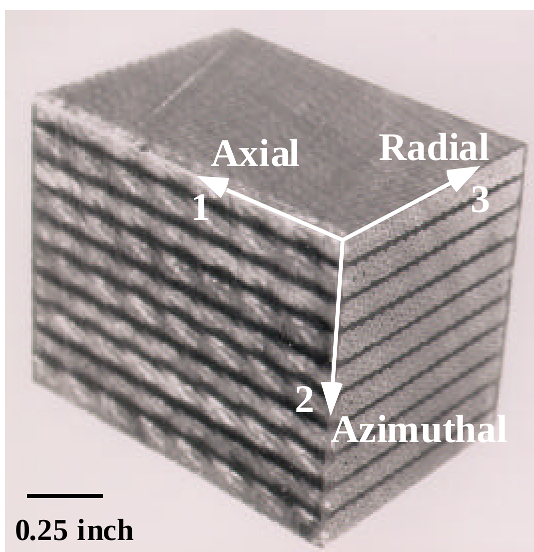


Fig. 1: *Epoxy impregnated NbTi composite. Also shown are the direction conventions.*

The testing fixture for room temperature measurements is as shown in Fig. 2. The fixture is also equipped with two Linear Variable Differential Transformers (LVDT's) to measure the displacement. In order to take in to account the machine compliance, measurements were also taken with a stainless steel master. This was necessary as the LVDT readings are affected by machine compliance (unlike strain gage readings)

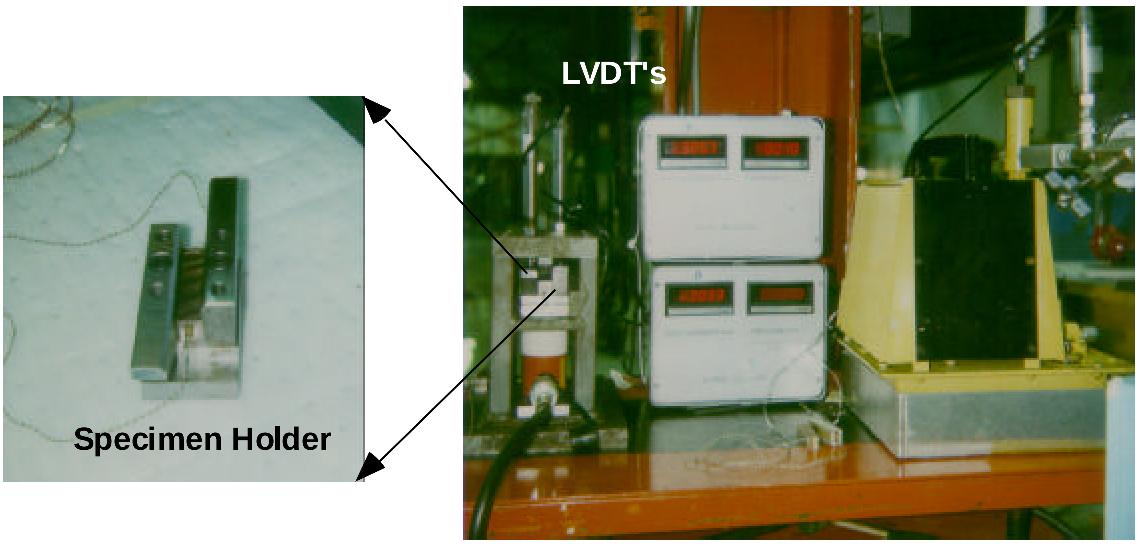


Fig. 2: *Testing fixture and the specimen holder for room temperature measurements.*

The strain gage results match quite well with that of the LVDT measurements (after subtracting the machine compliance). Fig. 3 shows the test results;

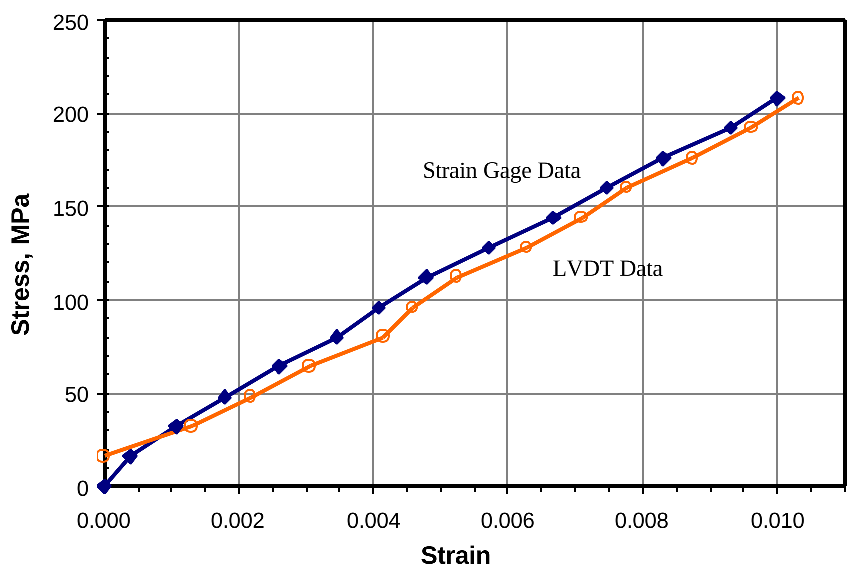


Fig. 3: *Comparison between the strain gage data and the LVDT output*.

A typical stress-strain curve for obtaining the modulus of elasticity and the Poisson's ratio is as shown in the Fig. 4. The specimen was loaded along the azimuthal direction and both azimuthal and radial strains were recorded. Note that the compression was taken to be positive and elongation to be negative.

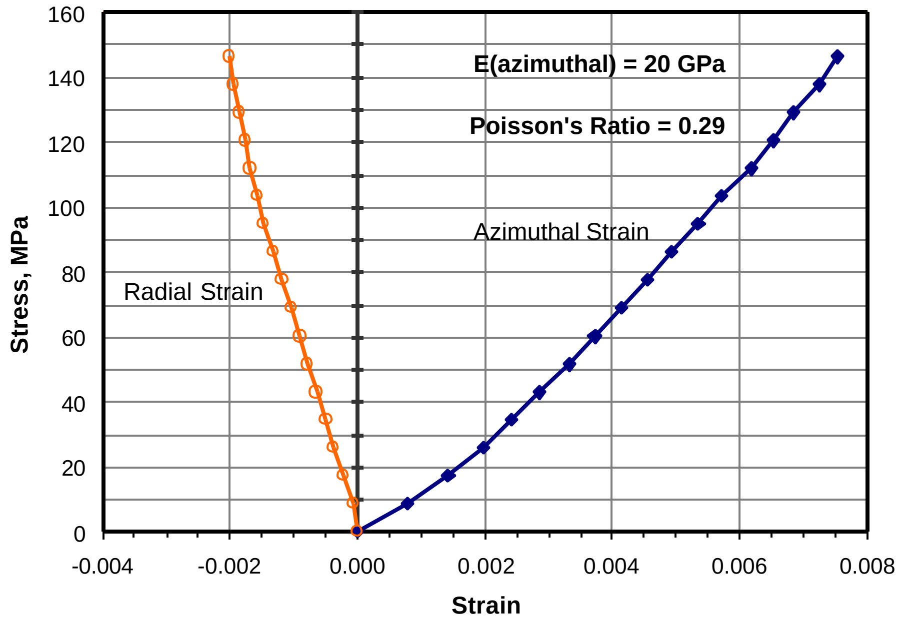


Fig. 4: *Stress-strain curves for an epoxy impregnated NbTi composite.*

The following table summarizes the test results:

Sample	Axial (E_{11}), GPa	Azimuthal (E_{22}), GPa	Radial (E_{33}), GPa	Poisson's Ratio
Sample 11: NbTi + burned S-2 + CTD-101K	19	21		
Sample 12: NbTi + burned S-2 + CTD-101K	20	19.4		$\nu_{23} = 0.28$ $\nu_{21} = 0.27$
Sample 16: NbTi + burned S-2 + CTD-101K		20	24	$\nu_{23} = 0.29$
Sample 10: NbTi + unburned S-2 +CTD-101 K	20	21		
Sample 9: Bare NbTi + CTD-101K	21	20.5		
Sample 5: Bare NbTi + 828 /NMA /DMP-30		18.6		
Sample 18: NbTi + burned S-2 + 828 /NMA /DMP-30	18	18.3		

Table 1: *Summary of test results at room temperature.*

The radial load was the most destructive of all. In fact we smashed the specimen during the test. The material yielded at around 80 MPa under radial load; if unsupported in azimuthal direction.

From the table the **average moduli** for an epoxy impregnated NbTi composite at room temperature are as follows:

Modulus (GPa)	with CTD-101K	with 828/NMA/DMP- 30
E_{11} (axial)	19.5	18.0
E_{22} (azimuthal)	20.1	18.3
E_{33} (radial)	24.0	

Table 2: *Average moduli of the epoxy impregnated NbTi composite.*

The mechanical properties of the composite with CTD-101K are slightly better than with 828/NMA/DMP-30. However the pot-life CTD-101K is much higher than that of 828/NMA/DMP-30 (see TD-98-059). This is particularly useful when impregnating long magnets.

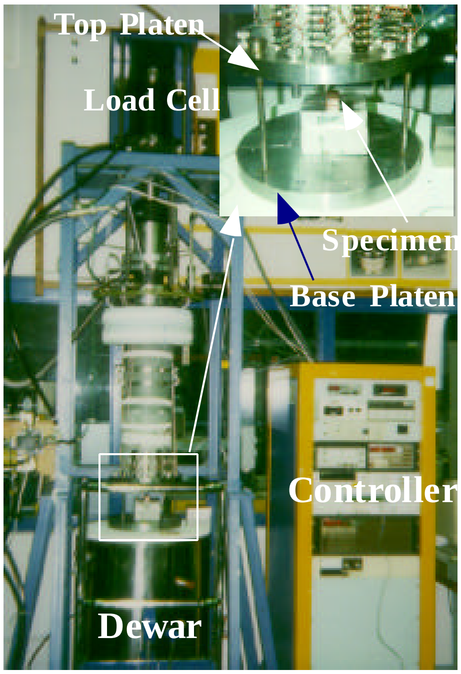
LOW TEMPERATURE MEASUREMENTS

Modulus measurements at liquid helium temperature (4.2 K) were performed using an already existing testing fixture in the Engineering Lab of Technical Division. This fixture was originally designed to calibrate the beam and capacitor gauges at low temperatures. Fig. 5 shows the testing apparatus. Specimen was placed on a base platen as shown in the Fig. 5(a). The base platen was then raised and bolted to the top platen. Note that the load is reacted against the base platen. The dewar was then lifted up and placed as shown in the Fig. 5(b). Liquid helium was transferred from a reservoir into the dewar through a transfer line. It takes about an hour to get the temperature down to 4.2 K. A pre-calibrated load cell gives the force being applied on the specimen and the strain gage read out gives the strain on the specimen. Note that the gage factor and the R_0, the reference resistance of the strain gage were taken at 4.2 K.

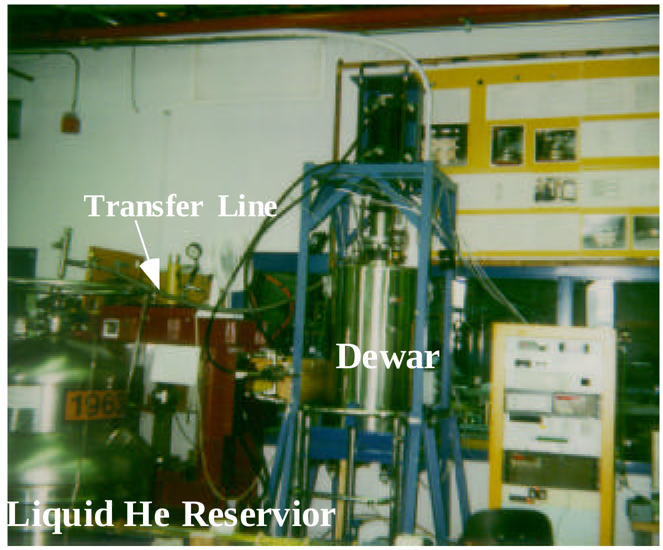
Before doing a cold test, the testing fixture was cross-checked with the previous warm measurements. The azimuthal modulus of the sample (impregnated with CTD-101K) at room temperature tested using this apparatus was found to be 19.5 GPa which compares well with that of the data shown in Table 1. Three cold tests were done; one each on azimuthal, axial and radial directions for samples impregnated with CTD-101K. The values are given below:

E_{11} (axial) = 46 GPa
E_{22} (azimuthal) = 32 GPa
E_{33} (radial) = 36 GPa

It is a good practice to check the repeatability of these measurements; especially the axial modulus in this case. Note that at room temperature all three moduli are close. We intend to get the statistics for low temperature measurements in future for Nb_3Sn samples (which is of interest for us).



(a)



(b)

Fig. 5: *Testing fixture for the low temperature (4.2 K) tests.*

Acknowledgments

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